NOTE

Relationship of First Hollow Stem and Heading in Winter Wheat

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ABSTRACT

The majority of wheat (*Triticum aestivum* L.) in the southern Great Plains is produced as a dual-purpose crop enterprise. Profitability of the system is highly dependent on removal of cattle (*Bos taurus* L.) from wheat pastures at the first-hollow-stem stage of growth. A previous survey implied that earliness of first hollow stem and earliness of heading are independent traits, which would allow a grower to select a cultivar with late first hollow stem without sacrificing early maturity. We evaluated first hollow stem and heading records for 52 hard winter wheat lines (49 commercially available winter wheat cultivars and three advanced experimental lines) during a 7-yr period at Stillwater, OK. Our analysis shows a positive, linear relationship between the occurrence of first hollow stem and heading in wheat when these phenological events were expressed as a function of cumulative thermal units after 1 January. When expressed in terms of calendar date, however, intervals between the earliest and latest cultivars for the first-hollow-stem stage were much greater than those for heading date. Overall, our analysis indicates that among commercially available cultivars and advanced experimental lines, choosing a cultivar with later occurrence of first hollow stem will also result in later heading in the same given environment.

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SOUTHERN GREAT PLAINS agriculture is dominated by the dual-purpose wheat (*Triticum aestivum* L.) production system (Hossain et al., 2004). In this system, wheat is typically sown in early September, grazed by cattle (*Bos taurus* L.) from mid-October until early March, and harvested for grain in early June (Krenzer, 1991). While wheat grain yields are frequently lower for dual-purpose wheat than for grain-only production (Edwards et al., 2005), the majority of wheat producers still prefer the dual-purpose system, as it provides a second source of income and spreads risk. Profitability of the system, however, is highly dependent on termination of grazing at the first-hollow-stem stage of wheat growth during late winter (Fieser et al., 2006; Redmon et al., 1996).

The first-hollow-stem stage occurs just after leaf sheaths are strongly erected (Feekes Stage 5; Large, 1954) and has been identified as the optimal wheat growth stage for removal of cattle from wheat pasture to optimize overall profitability of the dual-purpose system (Redmon et al., 1996). Therefore, late first hollow stem is a desirable characteristic for a dual-purpose wheat cultivar, as it allows later grazing in the spring than a cultivar with early first hollow stem.

Krenzer (2000) proposed that late development of first hollow stem is not phenologically associated with later heading or crop maturity. This is important, as hot, dry weather conditions frequently occur during wheat grain fill in the southern Great Plains, and this often results in drought and heat stress. Early-maturing

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wheat cultivars often have a yield advantage over later maturing cultivars in this environment, as drought and heat stress generally worsen during the grain-fill period. So, if late first hollow stem also resulted in later maturity, then the increased cattle gains associated with a longer grazing duration of late first-hollow-stem cultivars could be offset by decreased grain yield associated with suboptimal environmental conditions during grain fill of these same cultivars. In this study, we examined the relationship between first hollow stem and heading of some commercially available winter wheat cultivars and advanced experimental lines from the southern Great Plains.

MATERIALS AND METHODS

Data were collected from nonreplicated wheat cultivar plots from 1999 to 2005 at Stillwater, OK (97°05′ W, 36°07′ N). Soil type was a Kirkland silt loam (fine, mixed, superactive, thermic Udertic Paleustolls). Plots consisted of eight rows 15 cm wide by 12 m long and were sown within 2 d of 15 September each year, which is the typical planting date for dual-purpose wheat in the region. The seedbed was conventionally prepared and fertilized according to Oklahoma State University soil test recommendations for dual-purpose wheat. All plots were unirrigated and the cultivars evaluated varied by year (Table 1).

First-hollow-stem data were collected at approximate 3-d intervals beginning 15 February each year by removing plants from approximately 0.5 m of row at random locations in each plot. The 10 largest tillers from each sample were then selected, severed from the roots just above the crown, split longitudinally at the base, and measured for hollow stem (Redmon et al., 1996). The date of the first-hollow-stem stage was recorded when mean hollow stem length of a cultivar had reached 1.5 cm. Heading date was recorded as the date at which 50% of the heads were fully emerged in the same plots used for first-hollow-stem measurements.

Temperature data were collected using an on-site weather station and thermal units were calculated using a base temperature of 0°C (Baker et al., 1986). Thermal units until phenological events were calculated by summation of daily thermal units after 1 January. Using the PROC GLM function of SAS Version 9 (SAS Institute, Cary, NC), we tested for homogeneity of variances among years of the experiment by expressing thermal units until heading as a function of thermal units until first hollow

Table 1. Cultivars and advanced experimental lines included in analysis and least squares means for first hollow stem and heading at Stillwater, OK.

Cultivar or line	1999	2000	2001	2002	2003	2004	2005	Least square means: First hollow stem		Least square means: Heading	
								°C d†	DOY‡	°C d	DOY
2137	x§	x	x	x	x	x	x	376	69	928	111
2145				x	x	x	x	311	65	861	108
2158	x	x	x	x	x	x		394	72	928	111
2174	x	x	x	x	x	x	x	409	72	925	111
Above				x	x			318	70	826	109
AP502CL					x	x	x	248	59	782	103
Avalanche					x	x	x	294	64	869	108
Chisholm	x	x	x	x	x			399	72	898	110
Coronado	x	x	x	x	x			324	64	871	108
Cossack				x	x	x		422	79	920	113
Custer	x	x	x	x	x	x	x	325	63	879	108
Cutter				x	x	x	x	228	56	876	110
Cisco					x			345	76	837	112
Deliver					x	x	x	305	64	842	108
Dumas			x	x	x			350	76	863	111
Enhancer			x	x	x			360	77	848	111
Endurance					x	x	x	348	72	849	107
Fannin						x	x	253	58	812	102
G1878			x	x	x			367	76	879	112
Guymon						x	x	220	50	920	109
HG-9			x					401	82	925	116
Ike	x	x	x	x		x	x	428	75	986	113
Intrada	x	x	x	x	x	x	x	330	64	904	109
Jagalene				x	x	x	x	290	63	860	108
Jagger	x	x	x	x	x	x	x	284	59	851	106
Kalvesta			x	x	x			381	79	857	111
Lakin			x	x	x	x	x	417	78	883	110
Lockett	x	x	x	x				404	70	1016	116
Ogallala	x	x	x	x				341	64	965	112
OK Bullet						x	x	235	52	866	106
OK98697(exp)¶				x				453	81	950	114
OK98699(exp)				x	x			401	80	878	112
OK99212(exp)						x	x	283	58	839	105
Onaga			x	x				392	78	886	112
Ok101	x	x	x	x	x	x	x	351	66	841	108
Ok102				x	x	x	x	424	77	884	110
Okfield						x	x	312	62	909	108
Overley						x	x	185	47	790	100
Platte					x	x		321	71	934	114
Stanton						x	x	330	64	942	110
Sturdy 2K							x	363	64	889	106
TAM 107	x	x	x	x				383	67	911	109
TAM 110	x	x	x	x	x	x	x	303	61	849	106
TAM 111					x	x	x	306	66	875	109
TAM 202	x	x	x					325	61	953	111
TAM 302	x	x	x	x	x	x		400	73	951	113
Thunderbolt		x	x	x	x	x	x	344	68	916	111
Tomahawk	x		x					419	74	1002	114
Tonkawa	x	x	x					366	65	925	109
Trego		x	x	x	x	x	x	384	72	909	111
Triumph 64	x	x	x	x	x	x		414	74	939	111
Venango			x	x	x			375	78	911	115

†Thermal units since 1 January.

‡DOY = day of year.

§An x indicates that first hollow stem and heading date measurements were recorded for this wheat cultivar that year.

¶(exp) = advanced experimental line.

stem, with year as a covariate. The interaction of thermal units until first hollow stem and year was not significant ($P = 0.34$); therefore, data were pooled across years for analysis.

RESULTS AND DISCUSSION

Unlike previous reports, our data indicate a positive, linear relationship between the first-hollow-stem stage and heading date. This relationship was evident whether phenological events were expressed as calendar dates (Fig. 1A) or as thermal units after 1 January (Fig. 1B). While there was some variation unexplained by the linear models, our data clearly indicate that, among commercially available cultivars and advanced experimental lines, choosing a cultivar with later occurrence of first hollow stem will also result in later heading in the same given environment.

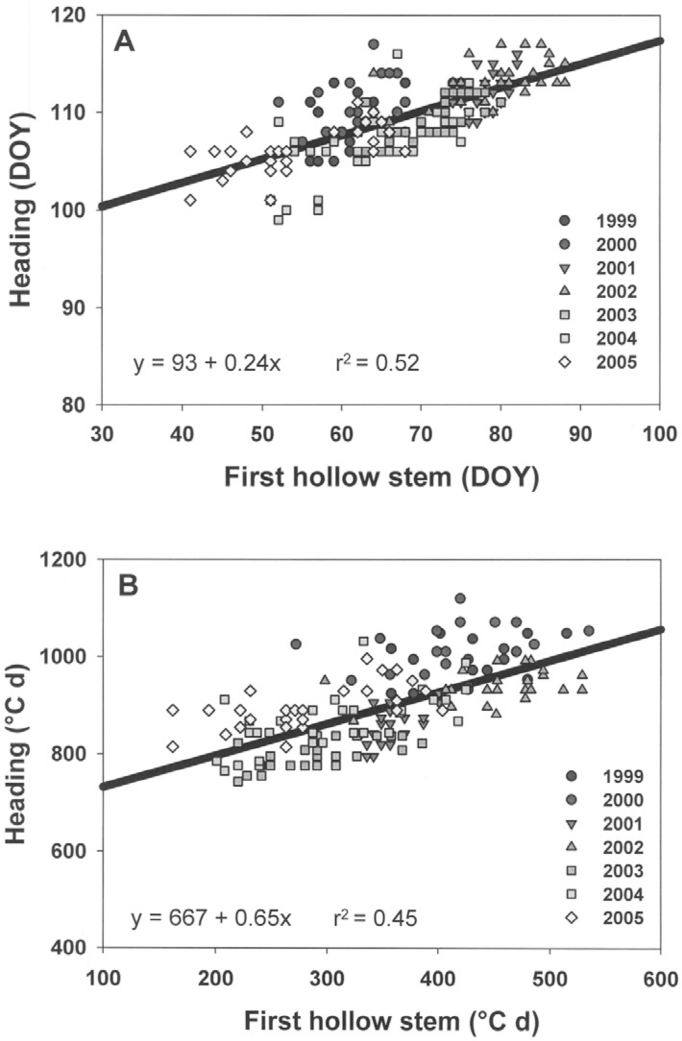

Figure 1. (A) Day of the year (DOY) of wheat heading and (B) thermal time until heading as a function of first hollow stem at Stillwater, OK, 1999 through 2005.

Table 2. Difference between earliest and latest cultivars in thermal time and days until first hollow stem and heading at Stillwater, OK.

Year	First-hollow-stem difference		Heading difference	
	Thermal time	Occurrence	Thermal time	Occurrence
	°C d	d	°C d	d
1999	157	19	124	8
2000	263	22	169	10
2001	75	8	130	7
2002	231	24	124	8
2003	166	17	94	6
2004	224	25	266	17
2005	242	27	181	10

The positive, linear relationship between first hollow stem and heading does not necessarily mean that a wheat producer who selects a cultivar with very late occurrence of first hollow stem will experience a much later harvest than would be associated with an early first-hollow-stem cultivar. Differences in average daily temperatures leading up to first hollow stem and heading, and the associated differences in how rapidly thermal units are accumulated, would compress the differences among cultivars in calendar heading dates more than the differences in calendar dates for first hollow stem. This may explain why previous reports (Krenzer, 2000) have indicated no relationship between the two phenological events. For example, there was a 157°C d difference among genotypes in thermal units until first hollow stem in 1999, which translated to a difference of 19 calendar days among 19 cultivars (Table 2). Likewise there was 124°C d difference among genotypes in heading, but this only translated to an eight calendar day difference among heading dates. Similar trends were observed for all years of the experiment, indicating that cooler temperatures before the occurrence of first hollow stem would allow growers to select cultivars with much later first hollow stem and provide an additional 14 to 21 d of grazing yet delay heading only 7 to 10 d.

Our data emphasize that both environmental and genotypic factors influence the onset of first hollow stem in winter wheat. Differences between the earliest and latest cultivars in thermal units until first hollow stem, for example, ranged from 75 to 242°C d among years of the experiment. This occurred even though planting date, management, and cultivars used were similar among all years. Further research is needed to develop a more mechanistic understanding of how environmental and genotypic factors influence wheat phenology in an early-sown, dual-use scenario.

Our analysis focused on a contemporary genetic pool of commercially released hard red and hard white winter wheat cultivars and three advanced experimental lines. Thus, our genetic sample represents a fixed set of lines with genes selected during cultivar development that confer a relatively narrow window for heading date. In addition, it is possible that genes were inadvertently selected that influenced the first-hollow-stem phenological trait as well. A logical extension of this phenotypic analysis is to examine the genotypic relationship between first hollow stem and heading date in a population of random lines produced by random assortment of genes influencing either or both traits. If extensive genetic variation does exist, it would be necessary to evaluate the physiological consequences of a shorter interval between first hollow stem and heading. A short interval, associated with late first hollow stem and early heading date, for example, might be associated with lower total biomass accumulation and lower grain yield.

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